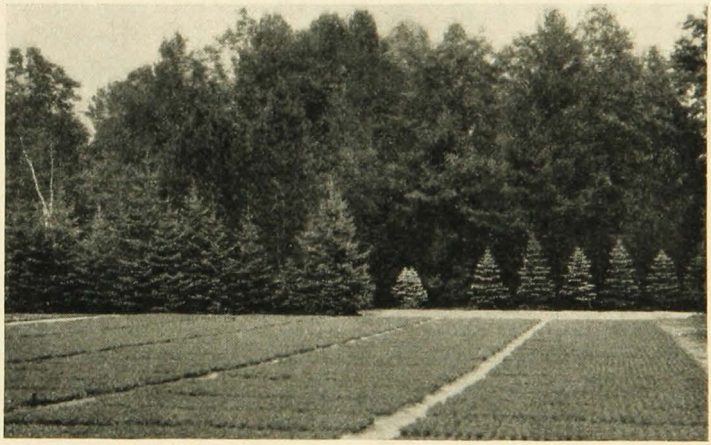
Bulletin 285 October 1931

UNIVERSITY OF MINNESOTA
AGRICULTURAL EXPERIMENT STATION

# ESTABLISHMENT, GROWTH, AND INFLUENCE OF SHELTER BELTS IN THE PRAIRIE REGION OF MINNESOTA

E. G. CHEYNEY
DIVISION OF FORESTRY



SHOWING THE COMPLETE PROTECTION FURNISHED BY A WIDE SHELTERBELT AND THE ORNAMENTAL ADVANTAGE OF SPRUCE IN THE INSIDE (PHOTO BY U. S. FOREST SERVICE)

UNIVERSITY FARM, ST. PAUL

## CONTENTS



## ILLUSTRATIONS

# THE ESTABLISHMENT, GROWTH, AND INFLUENCE OF SHELTER BELTS IN THE PRAIRIE REGION OF MINNESOTA

By E. G. CHEYNEY

## INTRODUCTION

A windbreak, or shelter belt, is an essential part of any prairie farm. There seems to be no well defined difference in the use of these two terms, "windbreak" and "shelter belt" but for the purposes of this bulletin "windbreak" will be used to indicate narrow strips consisting of only one or two rows of trees; "shelter belt," wide plantations of timber planted for the protection of homesteads or crops. Short-sighted land owners, anxious to devote every square foot of their land to the production of crops and livestock, have denied the advantages of windbreaks and begrudged them the growing space. The farmer often is only too likely to believe the exaggerated accounts of loss of crops through the shading and water-sapping qualities of the windbreaks and to overlook most of the benefits. However, there is plenty of evidence to show that these disadvantages are greatly outweighed by the advantages derived (3).

The benefits may be classified under several heads: Protection from the hot, dry winds of summer and the cold winds of winter; protection to man, to livestock, to orchards, and to field crops; a saving in fuel and an increased sale value for the farm.

Protection of man and the home from the cold winds of winter has been the most widely recognized and most widely practiced. Thousands of farmers will testify to the increased comfort of the home, the decreased consumption of fuel, and the comfort in doing chores behind a good windbreak. Many farmers can vouch for the increased sale value of a farm with a good windbreak (5). This is a factor of farm values very well recognized by the realtors who deal in farm land.

Man is not directly impressed with the benefits which accrue to livestock, and the results are not so apparent to general observation, but trained livestock workers do not hesitate to say that windbreaks are of almost inestimable value to animals in winter (1). Animals that can enjoy fresh air in the protection of a good windbreak are in far better condition in the spring than those which have been cooped up in a stable all winter, or exposed to the cold winds when they go outside. The man who has not extended his windbreak to his barns and paddocks has missed one of the best paying phases of windbreak protection.

A prominent animal husbandryman stated that a dairy calf that has enjoyed all the benefits of a well protected barnyard throughout the winter would be worth twice as much in the spring as one that had not had this advantage.

Those are the principal advantages of windbreak protection in winter. They are undoubtedly of great importance and contribute much to the comfort of farm life; but winter protection is rated by most experts as of far less economic value than summer protection (3).

Naturally, much less attention has been paid to the hot, dry winds of summer, which damage crop plants, than to the cold blasts of winter, which affect human and animal comfort; yet the summer damage is probably greater.

The benefits accruing to grain crops have been more or less obscured by the obvious decrease of the crop in the immediate vicinity of the shelter belt. This has been greatly exaggerated. It is true that grains do not head well in the shady, root-sapped area close to the trees, but Bates (3) has shown that this damage was more than offset by the increased crop beyond the reach of shade or of roots and yet within the influence of the windbreak. His experiments showed definitely that there was a very marked increase in the yield in a zone between one and ten tree-heights to the leeward of the windbreak. Moreover, the lodging of the grain was very much reduced in the protected area.

The same author also showed by records of the United States Weather Bureau that the violence of the winds in general had been materially reduced throughout the prairie regions where a large number of windbreaks had been established. This is especially true of the hot, dry winds of summer, which are of local origin and form over any large, sunbaked area of open plains.

The shelter belt in the future, probably planted on the south or west side of fields in the prairie region for the protection of crops from the hot southwest winds of summer, will be considered even more important and more valuable than the windbreak around the home. Certainly the use of both can be tremendously increased to the great advantage of the prairie farms. Windbreaks and shelter belts have been planted on the prairies of Minnesota for at least sixty years, but more were planted during the first twenty years of settlement than during the last forty years. This may be partly because the early settlers came from a wooded country and sorely missed the protecting timber and dreaded the ever-blowing winds.

Later on they became accustomed to these winds—their children had never known anything else—and the interest in windbreaks waned; few new ones were planted and the old ones were allowed to go to pieces from neglect.

As there is now just as much need for windbreaks as ever (4), it seems worth while to encourage the planting of new groves and the renewal of the old groves, which are now breaking up so fast.

Two classes of windbreaks are found in Minnesota: the old ones planted by settlers from twenty-five to forty years ago; the young demonstration windbreaks set out under the direction of the Division of Forestry, from seven to ten years ago. The history of the former class is not known, but they afford a good opportunity for the study of survival and rate of growth. The latter class is only from seven to ten years old, but its history is known in every detail and valuable data can be obtained from it.

## THE OLDER PLANTATIONS

The early settlers, when they first came to the prairies, naturally selected the fastest growing species with which they were familiar, such as cottonwood, willow, soft maple, and boxelder. In addition to being rapid growers these trees were all extremely hardy and were capable of growing well under very adverse conditions. Plantations of them were, therefore, very successful for the time being. Thousands succeeded and so changed the appearance of the country that much of it is scarcely recognizable at first glance as prairie.

Unfortunately, these fast-growing species were all river-bottom trees, used to moist soil and strange to the dry climate of the prairies. Their extraordinary vigor enabled them to succeed there for a while, but adverse conditions very materially shortened their lives (7). Now, after thirty to fifty years, they are beginning to die in the tops, and in a few years, probably, they will be dead (6).

It is unfortunate that the men who planted these groves so painstakingly did not know how to take care of them. Naturally, they planted the trees close together to get the best protection from the wind. They apparently did not realize that the trees would need more space as they grew, especially in the dry prairie climate. They did not favorably respond to suggestions to thin them out. The trees were allowed to crowd each other to death, or to come to a state of stagnation.

Also it is unfortunate that when these windbreaks were planted very little attention was paid to the possible drifting of snow, and many of them were placed too close to the farm buildings. The resulting snow drifts around the buildings have had a tendency to bring windbreaks into bad repute and cause people to overlook the manifold benefits derived from them.

Meanwhile, the windbreaks have been growing and can teach us much about the hardiness and rate of growth of the various species. They can tell us which trees are long lived under prairie conditions,

how far the windbreak should be from the buildings to prevent snow drifts in inconvenient places, and how wide a windbreak must be to prevent the formation of drifts. They can tell us, also, how much cordwood and lumber an acre of grove can produce in a year and many other valuable points (3).

Fig. 1. Inside of Willow Shelterbelt in Lyon County, Minn.
Notice how the dense cover of the trees shuts out undergrowth. (Photo by U. S. Forest Service.)

During the summer of 1926 the writer made a careful study of these old plantations from Watonwan and Rock Counties, in the south, to Polk County, in the northwest. Data were taken on the hardiness of different species, rate of growth, soil moisture and humidity inside and outside the windbreaks, and on the effect of windbreaks on wind velocity.

## SPACING

The spacing varies from 2 feet in rows 4 feet apart, to 4 feet in rows 6 to 8 feet apart. The more widely spaced trees are in the better condition, but even the widest spacing is too close for plantations of 25 or more years and in every case the trees are so crowded as to hamper growth. Those with the closer spacing are veritable jungles of badly stunted trees. Therefore the growth figures which follow fall short of what might be expected in plantations which have had

proper care. At that age trees of most species should not be closer than 10 to 15 feet apart.

It is impossible to tell now whether these groves were properly cultivated in early life, but it is perfectly clear that after they grew too large to be cultivated they have almost universally been wholly neglected.

## HARDINESS

It might have been expected that there would be considerable difference between the species in the southern and northern parts of the state, but such does not appear to be the case. There are fewer species in the north, but all those found there are also hardy in the south. Possibly more species were planted in the north and did not survive, but there is no evidence that that was the case.

Green ash (*Fraxinus pennsylvanica var. lanceolata*), white elm (*Ulmus americana*), boxelder (*Acer negundo*), eastern cottonwood (*Populus deltoides*), willow (*Salix sp.*), Russian olive (*Eleagnus augustifolia*), caragana (*Caragana arborescens*), blue spruce (*Picea pungens*), white spruce (*Picea glauca*), Scotch pine (*Pinus sylvestris*), Jack pine (*Pinus banksiana*), Norway pine (*Pinus resinosa*), and northern white pine (*Pinus strobus*), seem hardy everywhere in the prairie region of Minnesota without exception. Black walnut (*Juglans nigra*), which was found in a few plantations in the south, is wholly lacking in the north, and silver maple (*Acer saccharinum*), which plays a very important part in the southern counties, showed winter injury in at least three places in the north. These are the only points of difference noted. Other species occurred in small numbers, as northern white cedar (*Thuja occidentalis*), Austrian pine (*Pinus Austriaca*), balsam fir (*Abies balsamea*), butternut (*Juglans cinerea*), European larch (*Larix decidua*), Norway spruce (*Picea excelsa*), eastern red cedar (*Juniperus virginiana*), western yellow pine (*Pinus ponderosa*), and paper birch (*Betula papyrifera*).

None of the evergreens showed any winter injury in either the north or the south. Neither did they show any injury from drouth.

One the whole, green ash appeared to be the thriftiest species and the freest from injury of all kinds. The same thing was found true in Iowa.

The relative growth of the different species is shown in Tables 1 and 2. The data in these tables are based on the measurements of 8,553 trees.

## Table 1

## Average Diameter and Average Height of All Trees Measured, by Classes and Species

| Species | Age classes | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 16 to 25 years | | | 26 to 35 years | | | 36 to 45 years | | | 46 to 55 years | | |
| | Diameter | Height | No. trees | Diameter | Height | No. trees | Diameter | Height | No. trees | Diameter | Height | No. trees |
| | in. | ft. | | in. | ft. | | in. | ft. | | in. | ft. | |
| Eastern white cedar | .... | .. | ... | .... | .. | ... | 8.0 | 32 | 13 | .... | .. | ... |
| Austrian pine | .... | .. | ... | 8.2 | 32 | 61 | .... | .. | ... | .... | .. | ... |
| Balsam fir | .... | .. | ... | .... | .. | ... | 8.9 | 50 | 40 | .... | .. | ... |
| Black walnut | .... | .. | ... | 9.3 | 47 | 49 | .... | .. | ... | .... | .. | ... |
| Blue spruce | 4.3 | 18 | 15 | 6.0 | 29 | 87 | .... | .. | ... | .... | .. | ... |
| Boxelder | 7.0 | 40 | 600 | 6.8 | 35 | 107 | 7.3 | 50 | 214 | 7.6 | 52 | 79 |
| Butternut | .... | .. | ... | .... | .. | ... | 7.8 | 35 | 83 | .... | .. | ... |
| Eastern cottonwood | 13.3 | 70 | 141 | 11.7 | 75 | 369 | 11.7 | 80 | 606 | 14.9 | 65 | 125 |
| White elm | .... | .. | ... | 5.7 | 45 | 906 | 8.6 | 50 | 285 | .... | .. | ... |
| Green ash | 7.7 | 45 | 525 | 6.7 | 48 | 665 | 9.0 | 48 | 242 | 7.8 | 50 | 184 |
| Jack pine | 5.3 | 25 | 186 | .... | .. | ... | .... | .. | ... | .... | .. | ... |
| European larch | .... | .. | ... | 6.7 | 50 | 17 | 10.0 | 50 | 122 | .... | .. | ... |
| Norway pine | 5.4 | 18 | 55 | 8.2 | 28 | 53 | 8.4 | 39 | 274 | .... | .. | ... |
| Norway spruce | .... | .. | ... | 7.1 | 40 | 122 | 9.7 | 43 | 148 | .... | .. | ... |
| Eastern red cedar | .... | .. | ... | 7.0 | 26 | 13 | .... | .. | ... | .... | .. | ... |
| Scotch pine | 6.5 | 18 | 107 | 9.0 | 35 | 69 | 9.6 | 45 | 202 | 14.0 | 50 | 79 |
| Silver maple | 8.2 | 48 | 404 | 8.8 | 60 | 230 | 9.4 | 70 | 141 | 10.6 | 65 | 131 |
| Western yellow pine | .... | .. | ... | 7.1 | 30 | 51 | .... | .. | ... | .... | .. | ... |
| Paper birch | .... | .. | ... | 7.2 | 45 | 123 | .... | .. | ... | .... | .. | ... |
| Northern white pine | .... | .. | ... | 6.9 | 38 | 438 | .... | .. | ... | .... | .. | ... |
| White spruce | 5.4 | 15 | 69 | .... | .. | ... | .... | .. | ... | .... | .. | ... |
| White willow | 9.5 | 35 | 124 | .... | .. | ... | .... | .. | ... | .... | .. | ... |

## Table 2

## Number of Trees of Each Diameter Class in a 30-Year-Old Plantation, by Species

| Diameter* | Soft maple | | Boxelder | | Black walnut | | Green ash | | White elm | | Scotch pine | | European Larch | | Blue spruce | | Norway pine | | Norway spruce | | Cottonwood | | Eastern white pine | | Western yellow pine | | Austrian pine | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| in. | No. | per cent | No. | per cent | No. | per cent | No. | per cent | No. | per cent | No. | per cent | No. | per cent | No. | per cent | No. | per cent | No. | per cent | No. | per cent | No. | per cent | No. | per cent | No. | per cent |
| 2 | ... | .... | ... | .... | .. | .... | 9 | 1.4 | 7 | 0.8 | 1 | 1.5 | 2 | 11.7 | 4 | 4.6 | .. | .... | 5 | 4.1 | ... | .... | 1 | 0.3 | .. | .... | .. | .... |
| 3 | ... | .... | 3 | 2.8 | .. | .... | 29 | 4.4 | 63 | 7.0 | 4 | 5.8 | 1 | 5.9 | 5 | 5.7 | .. | .... | 7 | 5.7 | ... | .... | 5 | 1.1 | .. | .... | .. | .... |
| 4 | 3 | 1.3 | 9 | 8.4 | 2 | 4.1 | 61 | 9.2 | 207 | 22.8 | 4 | 5.8 | .. | .... | 15 | 17.2 | 3 | 5.7 | 6 | 4.9 | 7 | 1.9 | 18 | 4.1 | .. | .... | 4 | 6.6 |
| 5 | 6 | 2.6 | 14 | 13.1 | 1 | 2.0 | 93 | 14.0 | 202 | 22.3 | 5 | 7.3 | 3 | 17.7 | 14 | 16.1 | 2 | 3.8 | 15 | 12.3 | 16 | 4.2 | 71 | 16.2 | 7 | 13.7 | 2 | 3.3 |
| 6 | 25 | 10.9 | 27 | 25.2 | 4 | 8.2 | 123 | 18.5 | 162 | 17.9 | 3 | 4.3 | 3 | 17.7 | 15 | 17.2 | 9 | 16.9 | 20 | 16.4 | 15 | 4.0 | 92 | 21.0 | 12 | 23.5 | 9 | 14.7 |
| 7 | 32 | 13.9 | 23 | 21.5 | 5 | 10.2 | 132 | 19.8 | 107 | 11.8 | 1 | 1.4 | .. | .... | 10 | 11.5 | 5 | 9.4 | 19 | 15.6 | 22 | 6.0 | 99 | 22.6 | 12 | 23.5 | 7 | 11.5 |
| 8 | 40 | 17.4 | 10 | 9.3 | 8 | 16.3 | 100 | 15.0 | 77 | 8.4 | 6 | 8.7 | 3 | 17.7 | 9 | 10.4 | 10 | 19.0 | 16 | 13.1 | 28 | 7.6 | 74 | 16.9 | 12 | 23.5 | 12 | 19.6 |
| 9 | 44 | 19.1 | 12 | 11.2 | 7 | 14.3 | 55 | 8.3 | 45 | 5.0 | 9 | 13.0 | 2 | 11.7 | 12 | 13.8 | 8 | 15.1 | 9 | 7.4 | 31 | 8.4 | 51 | 11.6 | 6 | 11.8 | 10 | 16.4 |
| 10 | 33 | 14.3 | 4 | 3.8 | 7 | 14.3 | 30 | 4.4 | 15 | 1.7 | 9 | 13.0 | 1 | 5.9 | 2 | 2.3 | 9 | 16.9 | 11 | 9.0 | 28 | 7.6 | 22 | 5.0 | 1 | 2.0 | 9 | 14.7 |
| 11 | 24 | 10.4 | 2 | 1.9 | 3 | 6.1 | 13 | 2.0 | 7 | 0.8 | 13 | 18.9 | 2 | 11.7 | 1 | 1.2 | 4 | 7.5 | 7 | 5.7 | 30 | 8.2 | 4 | 0.9 | 1 | 2.0 | 4 | 6.6 |
| 12 | 12 | 5.2 | 2 | 1.9 | 5 | 10.2 | 12 | 1.8 | 7 | 0.8 | 6 | 8.7 | .. | .... | .. | .... | 1 | 1.9 | 4 | 3.3 | 32 | 8.7 | 1 | 0.3 | .. | .... | 2 | 3.3 |
| 13 | 8 | 3.5 | 1 | 0.9 | 4 | 8.2 | 6 | 0.9 | 2 | 0.2 | 5 | 7.3 | .. | .... | .. | .... | 2 | 3.8 | 3 | 2.5 | 26 | 7.1 | ... | .... | .. | .... | 2 | 3.3 |
| 14 | ... | .... | ... | .... | 2 | 4.1 | 2 | 0.3 | 5 | 0.5 | 3 | 4.3 | .. | .... | .. | .... | .. | .... | ... | .... | 35 | 9.5 | ... | .... | .. | .... | .. | .... |
| 15 | 2 | 0.9 | ... | .... | .. | .... | ... | .... | ... | .... | .. | .... | .. | .... | .. | .... | .. | .... | ... | .... | 29 | 7.9 | ... | .... | .. | .... | .. | .... |
| 16 | ... | .... | ... | .... | 1 | 2.0 | ... | .... | ... | .... | .. | .... | .. | .... | .. | .... | .. | .... | ... | .... | 229 | 7.9 | ... | .... | .. | .... | .. | .... |
| 17 | ... | .... | ... | .... | .. | .... | ... | .... | ... | .... | .. | .... | .. | .... | .. | .... | .. | .... | ... | .... | 12 | 3.3 | ... | .... | .. | .... | .. | .... |
| 18 | 1 | 0.5 | ... | .... | .. | .... | ... | .... | ... | .... | .. | .... | .. | .... | .. | .... | .. | .... | ... | .... | 12 | 3.3 | ... | .... | .. | .... | .. | .... |
| 19 | ... | .... | ... | .... | .. | .... | ... | .... | ... | .... | .. | .... | .. | .... | .. | .... | .. | .... | ... | .... | 11 | 3.0 | ... | .... | .. | .... | .. | .... |
| 20 | ... | .... | ... | .... | .. | .... | ... | .... | ... | .... | .. | .... | .. | .... | .. | .... | .. | .... | ... | .... | 3 | 0.8 | ... | .... | .. | .... | .. | .... |
| 21 | ... | .... | ... | .... | .. | .... | ... | .... | ... | .... | .. | .... | .. | .... | .. | .... | .. | .... | ... | .... | ... | .... | ... | .... | .. | .... | .. | .... |
| 22 | ... | .... | ... | .... | .. | .... | ... | .... | ... | .... | .. | .... | .. | .... | .. | .... | .. | .... | ... | .... | 1 | 0.3 | ... | .... | .. | .... | .. | .... |
| 23 | ... | .... | ... | .... | .. | .... | ... | .... | ... | .... | .. | .... | .. | .... | .. | .... | .. | .... | ... | .... | 1 | 0.3 | ... | .... | .. | .... | .. | .... |
| Total | 230 | 100.0 | 107 | 100.0 | 49 | 100.0 | 665 | 100.0 | 906 | 100.0 | 69 | 100.0 | 17 | 100.0 | 87 | 100.0 | 53 | 100.0 | 122 | 100.0 | 368 | 100.0 | 438 | 100.0 | 51 | 100.0 | 61 | 100.0 |

* Diameters measured at breast height.

## SOIL MOISTURE

The statement is often made that a windbreak saps all the moisture, not only from the ground on which it grows but from the fields on either side of it. To determine the justification for this statement, measurements of soil moisture, both within the plantation and 100 feet or more outside, were made at depths of one and two feet. In each case three holes were bored with a soil auger, and samples from the three borings were mixed to obtain a fair average. The combined sample was then placed immediately in an air-tight tin box and mailed to University Farm, where it was oven-dried and the moisture content determined on the basis of dry weight.

**Table 3**

**Soil Moisture Inside and Outside of Windbreaks in Percentage of Dry Weight of Soil**

| | At a depth of one foot | | | At a depth of two feet | | |
|---|---|---|---|---|---|---|
| | Inside windbreak | Outside windbreak | No. samples | Inside windbreak | Outside windbreak | No. samples |
| | per cent | per cent | | per cent | per cent | |
| Av. all samples ..... | 19.4 | 21.1 | 18 | 18.0 | 19.4 | 21 |
| Within 60 hours after all all-days rain ..... | 15.7 | 22.8 | 3 | 17.8 | 21.3 | 3 |
| One week after rain ... | 25.6 | 25.0 | 3 | 22.1 | 21.7 | 3 |

No great differences in soil moisture were discovered that could be used as a basis for classification. The soils, on the whole, appeared fairly uniform throughout the prairie region, from the southern boundary of the state to Canada. As the samples were taken at various times, and at various periods of time after rains, the measurements naturally show a great variation in moisture content.

However, one point appears quite consistently in most of the measurements. The samples taken within the windbreak show a slightly lower moisture content than those taken outside. This is in line with the findings of Bates (3) and of Bode, of Iowa Agricultural Experiment Station (4). The difference is not very great and whether or not the amount of rain intercepted by the forest would make up the difference is a question.

No attempt was made in this study to determine the distance outside the grove to which the sapping of moisture by the tree roots is felt, but both the authors cited above limit it to little more than the height of the trees. Both state that this distance can be considerably reduced by cultivating a strip between the windbreak and the field crop, or by digging, a ditch between them.

Samples for soil moisture determinations were taken under white pine, jack pine, cottonwood, willow, spruce, ash, boxelder, soft maple, and elm to see if there is any appreciable difference in the amount of

moisture a given species takes from the soil. There were slight differences but they seem neither consistent nor significant.

## SOIL TEMPERATURE

An attempt was made to study soil temperature at depths of one and two feet both inside and outside the windbreaks. In the time available, it was impossible to correlate properly the measurements with the density of the stand, the height of the trees, and the depth of the litter, but a rough comparison of the general conditions inside and outside the windbreaks was obtained. The results are recorded in Table 4.

**Table 4**

**Soil Temperatures (°C.) at One Foot and Two Feet Inside and Outside the Windbreaks**

| | Soil temperatures at one foot | | | Soil temperatures at two feet | | |
|---|---|---|---|---|---|---|
| | Inside windbreak | Outside windbreak | Excess on outside | Inside windbreak | Outside windbreak | Excess on outside |
| | 13.8 | 16.0 | 2.2 | 12.5 | 13.0 | 0.5 |
| | 20.0 | 23.0 | 3.0 | 18.0 | 22.0 | 4.0 |
| | 15.5 | 18.0 | 2.5 | 15.0 | 16.5 | 1.5 |
| | 13.8 | 17.5 | 3.7 | 12.6 | 15.6 | 3 0 |
| | 15.2 | 16.2 | 1.0 | 13.8 | 15.4 | 1.6 |
| | 14.7 | 18.0 | 3.3 | 14.4 | 17.5 | 3.1 |
| | 16.0 | 18.5 | 2.5 | 15.0 | 18.0 | 3.0 |
| | 16.7 | 15.8 | 0.9* | 17.2 | 17.0 | −2.0* |
| | 13.9 | 16.8 | 2.9 | 12.4 | 15.3 | 2.9 |
| | 15.0 | 16.6 | 1.6 | 13.5 | 15.0 | 1.5 |
| | 13.2 | 15.3 | 2.1 | 12.4 | 15.3 | 2.9 |
| Av. | 15.3 | 17.4 | 2.2 | 14.3 | 16.4 | 2.2 |

* — Indicates decrease.

On the whole, the temperature of the soil at both one foot and 2 feet below the surface is 2.1 degrees C. higher out in the open than within the grove.

A number of measurements were made in one place to determine the difference between the soil temperature under conifers and under broad-leaved trees. Under the conifers the temperature at one foot depth was only 1.8 degrees C. lower than at a corresponding depth outside the grove; at two feet it was 2 degrees C. lower. Under the deciduous trees, the temperature at one foot and at 2 feet was 2 degrees C. lower than at corresponding depths outside.

These results check roughly with the findings of Bates (3), who states that the difference in air temperature (he apparently did not measure soil temperature) was 3.22 degrees C.

## EFFECT OF WINDBREAKS ON WIND VELOCITY

An attempt was made to measure the influence of windbreaks in reducing wind velocity. Two small non-recording air meters were used. One was placed 100 feet or more to the windward of the windbreak to measure the wind velocity in the open. The other was placed at varying distances in the lee of the windbreak. They were allowed to run for five minutes in each location. The readings from both instruments were made at the end of each period and recorded.

**Table 5**

**Wind Velocity at Various Distances to Leeward of Windbreaks Compared With That Taken in the Open**

(In number of feet per 5-minute periods.)

| | Readings taken at | | | | | | |
|---|---|---|---|---|---|---|---|
| | Outer edge | Inner edge | 200 | 400 | 600 | 800 | Height of trees |
| | ft. | ft. | ft. | ft. | ft. | ft. | ft. |
| Windward ..... | .... | 3,165 | 2,415 | 2,955 | .... | .... | 45 |
| Leeward ..... | .... | 1,750 | 608 | 1,305 | .... | .... | .. |
| Windward ..... | 1,605 | 1,528 | 1,970 | 2,135 | .... | .... | 65 |
| Leeward ..... | 3,145 | 755 | 725 | 870 | .... | .... | .. |
| Windward ..... | 5,745 | 5,111 | 4,856 | 5,275 | 4,931 | .... | 45 |
| Leeward ..... | 3,958 | 222 | 3,153 | 3,470 | 2,723 | .... | .. |
| Windward ..... | 4,550 | 4,756 | 4,100 | 3,850 | .... | .... | 30 |
| Leeward ..... | 2,284 | 1,112 | 774 | 1,051 | .... | .... | .. |
| Windward ..... | 2,666 | 2,770 | 2,004 | 2,464 | 2,385 | 2,240 | 55 |
| Leeward ..... | 4,014 | 436 | 517 | 1,702 | 2,694 | 2,756 | .. |
| Windward ..... | 3,497 | 3,757 | 3,198 | 2,772 | 3,948 | .... | 42 |
| Leeward ..... | 2,492 | 1,455 | 625 | 616 | 1,412 | .... | .. |
| Windward ..... | .... | 4,300 | 4,211 | 3,296 | .... | .... | 50 |
| Leeward ..... | .... | 2,784 | 1,076 | 1,426 | .... | .... | .. |
| Windward ..... | .... | 2,949 | 3,319 | 3,239 | .... | .... | 40 |
| Leeward ..... | .... | —15* | 452 | 1,491 | .... | .... | .. |
| Windward ..... | .... | 1,956 | 1,959 | 1,765 | 1,740 | .... | 55 |
| Leeward ..... | .... | 1,398 | 241 | 384 | 485 | .... | .. |
| Windward ..... | .... | 3,566 | 4,049 | 3,945 | 4,144 | 2,925 | 70 |
| Leeward ..... | .... | 1,536 | 102 | 318 | 910 | 1,336 | .. |
| Windward ..... | .... | 2,864 | 3,644 | 3,164 | 2,884 | Single | 50 |
| Leeward ..... | .... | 3,372 | 2,647 | 1,302 | 2,107 | row | .. |
| Windward ..... | .... | 2,680 | 3,609 | 2,205 | .... | Single | 50 |
| Leeward ..... | .... | 3,752 | 2,065 | 2,223 | .... | row | .. |
| Av. reduction in velocity, per cent | 12 | 53 | 67 | 56 | 48 | .... | .. |

* Direction of wind reversed.

Unfortunately, one of the instruments was broken before the work had progressed very far and the number of readings obtained was too small to indicate conclusive results. However, several points of considerable interest were brought out.

Table 5 shows the effect of the windbreak on wind velocity at various distances to leeward. In every case there is an appreciable reduction at 600 feet. This checks roughly with Bates' (3) statement that the influence of the windbreak extends for a distance of at least ten tree heights.

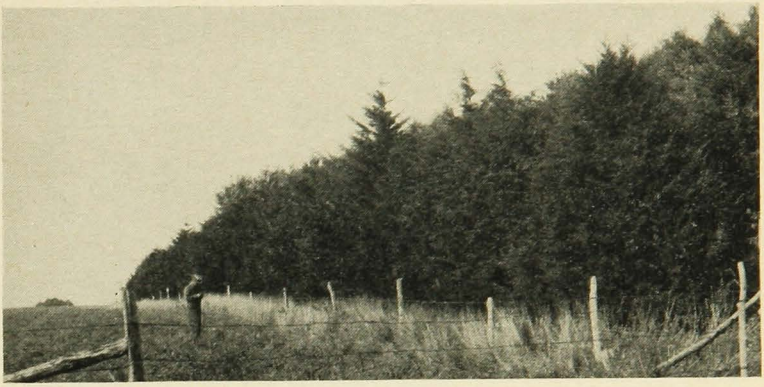


Fig. 2. A Red Cedar Windbreak (Photo by the U. S. Forest Service)
Red cedar would make a good windbreak except for the cedar apple disease.

In this study, wind velocity at 200 feet to leeward was found to be reduced 33 per cent. Bates (3) found it to be reduced 20 per cent at five tree heights. A measurement taken one foot above the ground between two trees of a single row of large willows indicates why such a row of trees causes such a heavy drifting of snow. The instrument read 18 per cent higher than the check instrument, and on a second reading 40 per cent higher. There was evidently a decided draft between those trees. That seems to explain why such quantities of snow are carried through and piled up back of the row.

The instrument was placed in the center of a 300-foot pasture between the south side of a large windbreak of trees and a single row of tall willows. The wind was blowing from the direction of the large windbreak. The pasture is in practically the same position as a snow trap.

While the check instrument recorded an air movement of 4,406 feet in five minutes in a southerly direction, the instrument in the pasture showed a movement of 390 feet in a northerly direction. The same phenomenon was observed in several other instances at a distance of 200 feet to leeward of very dense windbreaks. This is undoubtedly the same action which takes place in a snow trap. A vertical eddy is formed and that eddy draws the snow down into the trap. Bates (3) noted the same tendency.

## INFLUENCE ON CROPS

No attempt was made to determine the influence of the windbreaks on adjacent field crops. This was very thoroly covered by Bates (3). But whenever possible the owners were asked if they had noticed any difference in the crops to the north or east of the windbreaks, especially in years when there had been marked damage to crops from drying southwest winds. In most cases they had noted very decided superiority in those fields, but had not, in most instances, credited it to the windbreak.

## HUMIDITY

Psychrometer readings were taken within the windbreak at one foot from the ground and 7 feet from the ground in an attempt to determine the effect of the trees on the amount of moisture in the air. Similar readings were taken 100 feet or more to leeward of the windbreak in each case. The results are shown in Table 6.

**Table 6**

**Relative Humidity Inside and Outside of Windbreaks**

(Measurements taken at the surface and 7 feet above.)

| Age of trees | Relative humidity | | | | | |
|---|---|---|---|---|---|---|
| | Ground surface | | | Seven feet above ground | | |
| | Inside windbreak | Outside windbreak | Difference | Inside windbreak | Outside windbreak | Difference |
| years | per cent | per cent | per cent* | per cent | per cent | per cent* |
| 14 | 77 | 82 | + 5 | 68 | 73 | + 5 |
| 15 | 43 | 41 | — 2 | 41 | 42 | + 1 |
| 15 | 62 | 50 | —12 | 58 | 46 | — 8 |
| 25 | 48 | 43 | — 5 | 48 | 44 | — 4 |
| 28 | 84 | 80 | — 4 | 80 | 75 | — 5 |
| 30 | 64 | 66 | + 2 | 62 | 62 | 0 |
| 30 | 60 | 51 | — 9 | 51 | 53 | + 2 |
| 40 | 42 | 42 | 0 | 45 | 37 | — 8 |
| 40 | 38 | 27 | —11 | 35 | 28 | — 7 |
| 40 | 62 | 53 | — 9 | 61 | 47 | —14 |
| 40 | 49 | 54 | + 6 | 51 | 53 | + 2 |
| 40 | 57 | 62 | + 5 | 51 | 52 | + 1 |
| 47 | 71 | 80 | + 9 | 75 | 75 | 0 |
| 50 | 80 | 72 | — 8 | 70 | 71 | + 1 |
| Average | 59.8 | 57.4 | — 2.4 | 56.9 | 54.1 | — 2.8 |

* + Indicates higher humidity outside the grove.
— Indicates lower humidity outside the grove.

The readings taken at one foot above the ground outside the windbreak were 2.4 per cent lower than those taken at the same height within the windbreak. The readings taken in the open at 7 feet above the ground were 2.8 per cent lower than similar readings within the grove.

These figures, altho based on a small number of readings, seem to indicate that the windbreaks, when numerous enough, may be an important factor in raising the humidity of the air on the prairies and in mitigating the severity of the dry summer winds.

## GROWTH

The measurement of a large number of trees shows that eastern cottonwood makes the most rapid growth in height of any of the species and silver maple is next at all ages. American elm and green ash grow at approximately the same rate and both are considerably slower than silver maple. In general, the eastern cottonwood may be expected to grow about 2 feet in height per year for the first forty years, silver maple about 1¾ feet per year, and the other broad-leafed species from 1¼ to 1½ feet.

Fig. 3. A Windbreak of Scotch Pine Ten Feet High (Photo by U. S. Forest Service)
Note the long terminal shoots representing the last year's growth.

The evergreens, as a rule, grow more slowly than the hardwoods. Scotch pine, Norway spruce, Norway pine, northern white pine, and balsam fir make fairly rapid growth, but are much slower than green ash or American elm. In general, they may be counted on for about one foot a year for the first forty years, but they sometimes grow much more than that.

European larch is a conifer but not an evergreen. It is, therefore, of less value than evergreens for windbreaks. Its value as wind protection is probably much the same as that of the American elm or willow. It is by far the most rapidly growing conifer; in fact, it will in many cases equal or exceed the American elm.

Bates (3) has calculated, in considerable detail, the volume growth of the different species and what returns in the form of wood may be expected per acre of each windbreak species. According to his figures, cottonwood yields on the average $5.34 per acre per year; green ash $7.57; silver maple $2.07; and white willow $14.72.

Diameter growth is of comparatively little importance in a windbreak unless the windbreak serves also as a wood lot. The cottonwood outgrows all competitors in diameter as well as in height; but the faster growing conifers, such as European larch, Scotch pine, Norway pine, and balsam fir, all grow faster in diameter than the hardwoods. They will, therefore, produce a larger volume of wood in a given time (3).

The best growth recorded, and possibly one of the fastest growths ever recorded outside a eucalyptus grove, was found in a cottonwood grove five miles east of Wheaton, Minnesota. These trees are spaced $6 \times 8$ feet and are all alive. The diameters breast height of about half the trees were callipered, and some were measured for height with the hypsometer. The owner put the age of the trees at fifteen years.

The plantation is 125 feet wide and 600 feet long. The average tree was 9 inches D. B. H. and 57 feet high. Estimating 907 trees per acre and ten four-foot sticks 7 inches in diameter per tree, the stand represents 95 cords per acre, a growth of over 6⅓ cords per acre per year. Cottonwood cordwood sold there for $11 per cord.

Conditions there are unusually favorable to the growth of cottonwood. The surplus water from an artesian well stands in a lagoon beside the grove, and not more than 6 or 8 feet below it. But the growth is remarkable, even under the best of conditions.

## DEMONSTRATION WINDBREAKS

Many of the windbreaks planted by the pioneers are now dying out and the present generation of prairie dwellers seems not to be particularly interested in rejuvenating them.

To counteract this indifference and to encourage the planting of trees on the prairie, the Division of Forestry inaugurated a plan for setting out demonstration windbreaks in the prairie counties.

The plan was modeled after one used by the Northern Great Plains Experiment Station, at Mandan, North Dakota. Not more than two farmers in a township were selected by the county agent. The Division of Forestry co-operated with these farm owners in setting out model windbreaks on their prairie farms, using the most suitable species and the best arrangement the Division could devise. Methods of soil preparation, planting, and care were stipulated by the Division. Some 250 of these windbreaks were set out and careful touch with them was kept by annual inspections. Their histories are definitely known.

Many of the older plantations were of the "windbreak" type, only one or two rows of trees. The demonstration plantings are all of the "shelter belt" type and consist of from eight to ten rows of trees. The species used vary, but the general plan is the same: two rows of hardy trees or shrubs on the outside, a one-rod open space to serve

as a snow trap, and then six to eight rows of conifers and hardwoods with a row of spruce on the inside next to the buildings. This is considered a formation as nearly ideal as has yet been devised.

The five-, six- and seven-year-old plantations were used as the basis for the second part of this study.

Fig. 4. A Caragana Windbreak
A row of Caragana on the outside will effectually stop the snow and wind from blowing through. (Photo by the U. S. Forest Service.)

## SPECIES

The following species are found in the demonstration windbreaks: Jack pine (*Pinus banksiana*), Scotch pine (*Pinus sylvestris*), northern white pine (*Pinus strobus*), Norway pine (*Pinus resinosa*), Norway spruce (*Picea excelsa*), white spruce (*Picea glauca*), blue spruce (*Picea pungens*), and northern white cedar (*Thuja occidentalis*); Russian poplar (*Populus petrowskiana*), silver maple (*Acer saccharinum*), eastern cottonwood (*Populus deltoides*), white willow (*Salix alba*), laurel-leaf willow (*Salix laurifolia*), green ash (*Fraxinus pennsylvanica var. lanceolata*), American elm (*Ulmus americana*), Russian olive (*Eleagnus angustifolia*), boxelder (*Acer negundo*), and caragana (*Caragana arborescens*).

## EFFECT OF CULTIVATION

In attempting to classify the plantations there appears to be but one basis which means anything at all—the well cultivated plantations, and the poorly cultivated. Even in that several exceptions occur. Tables

7 to 26 show the increased growth which results in the well cultivated plantations.

Table 7

Height of American Elm at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6½ years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | 6 | ... | 1 | ... | ... | ... |
| 2 | 4 | 14 | 4 | ... | ... | ... |
| 3 | 5 | 19 | 8 | ... | ... | 5 |
| 4 | 9 | 16 | 15 | ... | 4 | 7 |
| 5 | 14 | 7 | 16 | ... | 3 | 16 |
| 6 | 20 | 13 | 17 | ... | 4 | 22 |
| 7 | 13 | 15 | 15 | ... | 5 | 17 |
| 8 | 8 | 9 | 9 | ... | 13 | 11 |
| 9 | 5 | 4 | 4 | ... | 11 | 9 |
| 10 | 7 | 3 | 8 | ... | 10 | 9 |
| 11 | 5 | ... | 2 | ... | 12 | 2 |
| 12 | 4 | ... | 1 | ... | 13 | 2 |
| 13 | ... | ... | ... | ... | 9 | ... |
| 14 | ... | ... | ... | ... | 9 | ... |
| 15 | ... | ... | ... | ... | 4 | ... |
| 16 | ... | ... | ... | ... | 2 | ... |
| 17 | ... | ... | ... | ... | ... | ... |
| 18 | ... | ... | ... | ... | ... | ... |
| 19 | ... | ... | ... | ... | 1 | ... |
| No. trees | 357 | 75 | 767 | ... | 768 | 377 |
| Mean annual height growth, ft. | 1.4 | 1.1 | 1.1 | ... | 1.6. | 1.0 |

* Based on the measurement of 2,344 trees.

Table 8

Height of Blue Spruce at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | 21 | ... | 27 | ... | 20 | 3 |
| 2 | 52 | ... | 37 | ... | 52 | 29 |
| 3 | 26 | ... | 27 | ... | 13 | 36 |
| 4 | 1 | ... | 8 | ... | 9 | 20 |
| 5 | ... | ... | 1 | ... | 2 | 9 |
| 6 | ... | ... | ... | ... | 1 | 3 |
| 7 | ... | ... | ... | ... | 1 | ... |
| 8 | ... | ... | ... | ... | 1 | ... |
| 9 | ... | ... | ... | ... | 1 | ... |
| No trees | 99 | ... | 275 | ... | 141 | 202 |
| Mean annual height growth, ft. | 0.34 | ... | 0.29 | ... | 0.27 | 0.40 |

* Based on the measurement of 717 trees.

## Table 9

### Height of Boxelder at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | ... | ... | ... | ... | ... | ... |
| 2 | 2 | 5 | ... | ... | 2 | ... |
| 3 | 6 | 28 | ... | 2 | 8 | 2 |
| 4 | 17 | 34 | 2 | 3 | 3 | 6 |
| 5 | 25 | 19 | ... | 10 | 4 | 14 |
| 6 | 25 | 11 | 4 | 19 | 5 | 18 |
| 7 | 21 | 3 | 7 | 33 | 5 | 27 |
| 8 | 4 | ... | 17 | 16 | 9 | 9 |
| 9 | ... | ... | 40 | 11 | 10 | 6 |
| 10 | ... | ... | 26 | 6 | 15 | 13 |
| 11 | ... | ... | 4 | ... | 15 | 4 |
| 12 | ... | ... | ... | ... | 11 | 1 |
| 13 | ... | ... | ... | ... | 6 | ... |
| 14 | ... | ... | ... | ... | 5 | ... |
| 15 | ... | ... | ... | ... | 2 | ... |
| 16 | ... | ... | ... | ... | ... | ... |
| No. trees | 114 | 62 | 53 | 156 | 885 | 131 |
| Mean annual height growth, ft. | 1.18 | 0.96 | 1.64 | 1.26 | 1 45 | 1.07 |

* Based on the measurement of 1,401 trees.

## Table 10

### Height of Caragana at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | 2 | ... | ... | ... | ... | 1 |
| 2 | 10 | ... | 8 | ... | ... | 17 |
| 3 | 10 | ... | 20 | 3 | ... | 54 |
| 4 | 29 | ... | 35 | 30 | ... | 24 |
| 5 | 32 | ... | 19 | 43 | 2 | 4 |
| 6 | 16 | ... | 16 | 22 | 13 | ... |
| 7 | 1 | ... | 2 | 2 | 25 | ... |
| 8 | ... | ... | ... | ... | 31 | ... |
| 9 | ... | ... | ... | ... | 19 | ... |
| 10 | ... | ... | ... | ... | 10 | ... |
| No. trees | 692 | ... | 357 | 169 | 68 | 190 |
| Mean annual height growth, ft. | 0.85 | ... | 0.71 | 0.82 | 1.4 | 0.4 |

* Based on the measurement of 1,476 trees.

## Table 11

### Height of Eastern Cottonwood at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | ... | ... | ... | ... | ... | ... |
| 2 | ... | ... | ... | ... | ... | ... |
| 3 | ... | ... | ... | ... | ... | ... |
| 4 | 7 | ... | ... | ... | ... | ... |
| 5 | 30 | ... | ... | ... | ... | 3 |
| 6 | 35 | ... | ... | ... | 1 | 5 |
| 7 | 9 | ... | 4 | ... | 3 | 8 |
| 8 | 1 | ... | ... | ... | 7 | 11 |
| 9 | ... | ... | 7 | ... | 14 | 9 |
| 10 | 2 | ... | 7 | ... | 28 | 14 |
| 11 | 4 | ... | 17 | ... | 16 | 13 |
| 12 | 8 | ... | 20 | ... | 14 | 8 |
| 13 | 3 | ... | 13 | ... | 10 | 12 |
| 14 | 1 | ... | 15 | ... | 5 | 11 |
| 15 | ... | ... | 13 | ... | 2 | 4 |
| 16 | ... | ... | 4 | ... | ... | 2 |
| No. trees | 152 | ... | 46 | ... | 226 | 375 |
| Mean annual height growth, ft. | 1.52 | ... | 2.36 | ... | 1.67 | 1.65 |

* Based on the measurement of 799 trees.

## Table 12

### Height of Green Ash at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | ... | ... | ... | ... | ... | ... |
| 2 | 2 | 2 | 2 | ... | ... | ... |
| 3 | 14 | 20 | 5 | 1 | 2 | 1 |
| 4 | 13 | 27 | 5 | 5 | 3 | 5 |
| 5 | 12 | 16 | 9 | 21 | 6 | 12 |
| 6 | 20 | 11 | 18 | 22 | 7 | 18 |
| 7 | 20 | 17 | 20 | 27 | 11 | 18 |
| 8 | 11 | 7 | 16 | 19 | 8 | 15 |
| 9 | 6 | ... | 11 | 3 | 11 | 13 |
| 10 | 2 | ... | 8 | 2 | 15 | 9 |
| 11 | ... | ... | 4 | ... | 11 | 7 |
| 12 | ... | ... | 2 | ... | 9 | 2 |
| 13 | ... | ... | ... | ... | 8 | ... |
| 14 | ... | ... | ... | ... | 4 | ... |
| 15 | ... | ... | ... | ... | 3 | ... |
| 16 | ... | ... | ... | ... | 1 | ... |
| 17 | ... | ... | ... | ... | 1 | ... |
| No. trees | 376 | 246 | 421 | 175 | 1,403 | 871 |
| Mean annual height growth, ft. | 1.28 | 1.05 | 1.28 | 1.16 | 1.48 | 0.96 |

* Based on the measurement of 3,492 trees.

## Table 13

### Height of Jack Pine at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | 30 | ... | 1 | ... | 1 | 8 |
| 2 | 19 | ... | 5 | 3 | 3 | 16 |
| 3 | 23 | ... | 12 | 3 | 4 | 28 |
| 4 | 18 | ... | 18 | 7 | 4 | 18 |
| 5 | 7 | ... | 19 | 13 | 9 | 10 |
| 6 | 3 | ... | 21 | 3 | 11 | 6 |
| 7 | ... | ... | 16 | 20 | 11 | 9 |
| 8 | ... | ... | 5 | 17 | 17 | 5 |
| 9 | ... | ... | 3 | 7 | 19 | ... |
| 10 | ... | ... | ... | 20 | 17 | ... |
| 11 | ... | ... | ... | 7 | 4 | ... |
| No. trees | 359 | ... | 334 | 30 | 747 | 131 |
| Mean annual height growth, ft. | 0.49 | ... | 0.90 | 1.34 | 1.13 | 0.53 |

* Based on the measurement of 1,601 trees.

## Table 14

### Height of Laurel-Leaf Willow at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | ... | ... | ... | ... | ... | ... |
| 2 | ... | ... | ... | ... | ... | ... |
| 3 | ... | ... | ... | ... | ... | ... |
| 4 | 5 | 26 | 2 | 8 | 1 | 2 |
| 5 | 17 | 26 | ... | 8 | 4 | 3 |
| 6 | 26 | 18 | 8 | 4 | 3 | 21 |
| 7 | 28 | 17 | 16 | 17 | 11 | 38 |
| 8 | 20 | 4 | 16 | 10 | 12 | 12 |
| 9 | 1 | 9 | 31 | 4 | 6 | 10 |
| 10 | 3 | ... | 24 | 15 | 11 | 13 |
| 11 | ... | ... | 3 | 6 | 13 | 1 |
| 12 | ... | ... | ... | 13 | 10 | ... |
| 13 | ... | ... | ... | 11 | 10 | ... |
| 14 | ... | ... | ... | 4 | 11 | ... |
| 15 | ... | ... | ... | ... | 3 | ... |
| 16 | ... | ... | ... | ... | 3 | ... |
| 17 | ... | ... | ... | ... | 1 | ... |
| 18 | ... | ... | ... | ... | ... | ... |
| 19 | ... | ... | ... | ... | 1 | ... |
| No. trees | 107 | 23 | 62 | 48 | 172 | 68 |
| Mean annual height growth, ft. | 1.45 | 1.22 | 1.58 | 1.66 | 1.66 | 1.15 |

* Based on the measurement of 480 trees.

## Table 15

### Height of Northern White Cedar at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | 45 | ... | 22 | ... | 5 | ... |
| 2 | 48 | ... | 41 | ... | 25 | ... |
| 3 | 6 | ... | 33 | ... | 18 | ... |
| 4 | 1 | ... | 3 | ... | 24 | ... |
| 5 | ... | ... | 1 | ... | 16 | ... |
| 6 | ... | ... | ... | ... | 10 | ... |
| 7 | ... | ... | ... | ... | 2 | ... |
| No. trees | 217 | ... | 164 | ... | 351 | ... |
| Mean annual height growth, ft. | 0.24 | ... | 0.30 | ... | 0.47 | ... |

* Based on the measurement of 732 trees.

## Table 16

### Height of Northern White Pine at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | 4 | ... | ... | ... | 6 | ... |
| 2 | 40 | ... | ... | 7 | 17 | ... |
| 3 | 49 | ... | ... | 24 | 21 | ... |
| 4 | 7 | ... | ... | 25 | 13 | ... |
| 5 | ... | ... | ... | 27 | 11 | ... |
| 6 | ... | ... | ... | 12 | 7 | ... |
| 7 | ... | ... | ... | 5 | 6 | ... |
| 8 | ... | ... | ... | ... | 6 | ... |
| 9 | ... | ... | ... | ... | 5 | ... |
| 10 | ... | ... | ... | ... | 6 | ... |
| 11 | ... | ... | ... | ... | 2 | ... |
| No. trees | 68 | ... | ... | 41 | 443 | ... |
| Mean annual height growth, ft. | 0.47 | ... | ... | 0.72 | 0.66 | ... |

* Based on the measurement of 552 trees.

## Table 17

### Height of Norway Pine at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | 11 | ... | 7 | ... | 5 | 17 |
| 2 | 34 | ... | 32 | ... | 22 | 28 |
| 3 | 38 | ... | 34 | ... | 26 | 16 |
| 4 | 14 | ... | 19 | ... | 20 | 17 |
| 5 | 3 | ... | 6 | ... | 14 | 13 |
| 6 | ... | ... | 1 | ... | 7 | 8 |
| 7 | ... | ... | 1 | ... | 3 | 1 |
| 8 | ... | ... | ... | ... | 3 | ... |
| No. trees | 392 | ... | 289 | ... | 631 | 259 |
| Mean annual height growth, ft. | 0.49 | ... | 0.44 | ... | 0.49 | 0.40 |

* Based on the measurement of 1,571 trees.

## Table 18

### Height of Norway Spruce at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | ... | ... | 16 | ... | 1 | 24 |
| 2 | ... | ... | 52 | ... | 17 | 25 |
| 3 | ... | ... | 26 | ... | 27 | 26 |
| 4 | ... | ... | 6 | ... | 34 | 19 |
| 5 | ... | ... | ... | ... | 11 | 6 |
| 6 | ... | ... | ... | ... | 9 | ... |
| 7 | ... | ... | ... | ... | 1 | ... |
| No. trees | ... | ... | 82 | ... | 77 | 128 |
| Mean annual height growth, ft. | ... | ... | 0.30 | ... | 0.40 | 0.30 |

* Based on the measurement of 287 trees.

## Table 19

### Height of Northwest Poplar at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | ... | ... | ... | ... | ... | ... |
| 2 | ... | ... | ... | ... | ... | ... |
| 3 | ... | ... | ... | ... | ... | ... |
| 4 | ... | ... | 1 | ... | 2 | ... |
| 5 | ... | ... | 1 | ... | 3 | ... |
| 6 | 6 | ... | 6 | ... | ... | ... |
| 7 | 4 | ... | 10 | ... | ... | ... |
| 8 | 18 | ... | 12 | ... | ... | ... |
| 9 | 21 | ... | 8 | ... | ... | ... |
| 10 | 35 | ... | 17 | ... | ... | ... |
| 11 | 10 | ... | 17 | ... | ... | ... |
| 12 | 6 | ... | 17 | ... | 11 | ... |
| 13 | ... | ... | 10 | ... | 27 | ... |
| 14 | ... | ... | 1 | ... | 20 | ... |
| 15 | ... | ... | ... | ... | 33 | ... |
| 16 | ... | ... | ... | ... | 4 | ... |
| No. trees | 49 | ... | 102 | ... | 55 | ... |
| Mean annual height growth, ft. | 2.18 | ... | 2.1 | ... | 2.2 | ... |

* Based on the measurement of 206 trees.

## Table 20

### Height of Russian Olive at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | ... | ... | 1 | ... | ... | ... |
| 2 | ... | ... | 9 | ... | ... | ... |
| 3 | 3 | 1 | 10 | ... | ... | ... |
| 4 | 5 | 4 | 6 | ... | ... | ... |
| 5 | 17 | 7 | 4 | ... | ... | ... |
| 6 | 17 | 25 | 5 | ... | ... | ... |
| 7 | 25 | 31 | 7 | ... | ... | ... |
| 8 | 30 | 23 | 11 | ... | ... | ... |
| 9 | 3 | 8 | 15 | ... | ... | ... |
| 10 | ... | 1 | 18 | ... | ... | ... |
| 11 | ... | ... | 10 | ... | ... | ... |
| 12 | ... | ... | 4 | ... | ... | ... |
| No. trees | 36 | 166 | 201 | ... | ... | ... |
| Mean annual height growth, ft. | 1.50 | 1.55 | 1.34 | ... | ... | ... |

* Based on the measurement of 403 trees.

## Table 21

### Height of Russian Poplar at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | 1 | ... | ... | ... | ... | ... |
| 2 | 3 | ... | ... | 1 | 1 | 12 |
| 3 | 7 | ... | ... | 3 | 8 | 28 |
| 4 | 9 | ... | 2 | 8 | 2 | 22 |
| 5 | 20 | ... | 2 | 13 | 7 | 16 |
| 6 | 7 | ... | 6 | 13 | 13 | 18 |
| 7 | 8 | ... | 5 | 20 | 12 | 2 |
| 8 | 11 | ... | 8 | 13 | 8 | 2 |
| 9 | 7 | ... | 11 | 15 | 4 | ... |
| 10 | 5 | ... | 30 | 11 | 3 | ... |
| 11 | 2 | ... | 22 | 2 | 6 | ... |
| 12 | 2 | ... | 14 | 1 | 2 | ... |
| 13 | 1 | ... | ... | ... | 4 | ... |
| 14 | 2 | ... | ... | ... | 6 | ... |
| 15 | 1 | ... | ... | ... | 6 | ... |
| 16 | 2 | ... | ... | ... | 6 | ... |
| 17 | 3 | ... | ... | ... | 9 | ... |
| 18 | 4 | ... | ... | ... | 3 | ... |
| 11 | 3 | ... | ... | ... | ... | ... |
| 20 | 1 | ... | ... | ... | ... | ... |
| 21 | 1 | ... | ... | ... | ... | ... |
| No. trees | 230 | ... | 135 | 201 | 146 | 137 |
| Mean annual height growth, ft. | 1.91 | ... | 1.82 | 1.28 | 1.53 | 0.57 |

* Based on the measurement of 849 trees.

## Table 22

### Height of Scotch Pine at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | 10 | ... | 5 | ... | 4 | 3 |
| 2 | 28 | ... | 26 | ... | 12 | 12 |
| 3 | 28 | ... | 32 | ... | 14 | 16 |
| 4 | 20 | ... | 17 | ... | 14 | 10 |
| 5 | 12 | ... | 7 | ... | 18 | 15 |
| 6 | 2 | ... | 5 | ... | 15 | 16 |
| 7 | ... | ... | 2 | ... | 13 | 16 |
| 8 | ... | ... | 2 | ... | 7 | 9 |
| 9 | ... | .. | 4 | ... | 3 | 3 |
| No. trees | 311 | ... | 246 | ... | 688 | 280 |
| Mean annual height growth, ft. | 0.58 | ... | 0.56 | ... | 0.68 | 0.72 |

* Based on the measurement of 1,525 trees.

## Table 23

### Height of Silver Maple at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | ... | ... | ... | ... | ... | ... |
| 2 | ... | ... | ... | ... | ... | ... |
| 3 | ... | ... | ... | ... | 2 | 5 |
| 4 | ... | ... | ... | ... | 2 | 7 |
| 5 | ... | ... | ... | ... | 2 | 18 |
| 6 | ... | ... | ... | ... | 2 | 16 |
| 7 | ... | ... | 3 | ... | 3 | 21 |
| 8 | ... | ... | 5 | ... | 3 | 17 |
| 9 | ... | ... | 15 | ... | 6 | 8 |
| 10 | ... | ... | 37 | ... | 7 | 8 |
| 11 | ... | ... | 20 | ... | 11 | ... |
| 12 | ... | ... | 10 | ... | 10 | ... |
| 13 | ... | ... | 8 | ... | 10 | ... |
| 14 | ... | ... | 2 | ... | 10 | ... |
| 15 | ... | ... | ... | ... | 9 | ... |
| 16 | .. | ... | ... | ... | 7 | ... |
| 17 | ... | ... | ... | ... | 8 | ... |
| 18 | ... | ... | ... | ... | 6 | ... |
| 19 | ... | ... | ... | ... | 2 | ... |
| No. trees | ... | ... | 137 | ... | 1,128 | 61 |
| Mean annual height growth, ft. | ... | ... | 1.96 | ... | 2.00 | 0.98 |

* Based on the measurement of 1,326 trees.

## Table 24

### Height of White Spruce at Different Ages and Under Different Degrees of Cultivation*

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | 44 | ... | 20 | 3 | 15 | 50 |
| 2 | 39 | ... | 59 | 35 | 36 | 33 |
| 3 | 11 | ... | 19 | 43 | 17 | 17 |
| 4 | 6 | ... | 2 | 16 | 14 | ... |
| 5 | ... | ... | ... | 3 | 11 | ... |
| 6 | ... | ... | ... | ... | 3 | ... |
| 7 | ... | ... | ... | ... | 2 | ... |
| 8 | ... | ... | ... | ... | 1 | ... |
| 9 | ... | ... | ... | ... | 1 | ... |
| No. trees | 419 | ... | 211 | 61 | 597 | 12 |
| Mean annual height growth, ft. | 0.31 | ... | 0.26 | 0.42 | 0.37 | 0.17 |

* Based on the measurement of 1,300 trees.

Table 25

**Height of White Willow at Different Ages and Under Different Degrees of Cultivation***

| Height | 4 years after planting | | 5 years after planting | | 6 years after planting | |
|---|---|---|---|---|---|---|
| | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated | Well cultivated | Poorly cultivated |
| ft. | per cent | per cent | per cent | per cent | per cent | per cent |
| 1 | ... | ... | ... | ... | ... | ... |
| 2 | ... | ... | ... | ... | ... | 1 |
| 3 | ... | 33 | ... | ... | ... | 10 |
| 4 | ... | 33 | ... | ... | ... | 20 |
| 5 | ... | 34 | ... | ... | 1 | 17 |
| 6 | ... | ... | ... | ... | 2 | 18 |
| 7 | ... | ... | ... | ... | ... | 9 |
| 8 | ... | ... | ... | ... | 1 | 11 |
| 9 | ... | ... | ... | ... | 6 | 4 |
| 10 | ... | ... | 46 | ... | 11 | 4 |
| 11 | ... | ... | 18 | ... | 12 | 4 |
| 12 | ... | ... | 18 | ... | 18 | 2 |
| 13 | ... | ... | 9 | ... | 23 | ... |
| 14 | ... | ... | 9 | ... | 12 | ... |
| 15 | ... | ... | ... | ... | 11 | ... |
| 16 | ... | ... | ... | ... | 2 | ... |
| 17 | ... | ... | ... | ... | 1 | ... |
| No. trees | ... | 3 | 11 | ... | 153 | 135 |
| Mean annual height growth, ft. | ... | 0.79 | 2.12 | ... | 1.95 | 0.88 |

* Based on the measurement of 302 trees.

Russian olive is the only exception among the hardwoods that shows an increased growth under poor cultivation. The result was obtained by measuring about 400 trees almost equally divided between the two classes. No satisfactory explanation was found for this exception. It is also able to grow in more alkaline soil than other species.

Blue spruce and Scotch pine also show better results under poor cultivation, but comparatively few trees are in the poorly cultivated class and the difference is slight.

In most cases the result of cultivation is very marked. A fence crossed one windbreak. The two-thirds of the windbreak on one side of the fence had been faithfully cultivated; the third on the other side completely neglected. The cultivated part stood 3 to 4 feet above the other and looked at least two years older.

Cultivation no doubt is of as much value to a tree crop as to any other crop. In plantations which are over-run with weeds, both the growth and the thriftiness of the trees were evidently impaired. Nor does the worst of the damage show in the growth figures. In some of the most neglected plantations only a few of the trees are left. The percentage of survival could not be determined accurately, because it was not possible, in many cases, to know how many of the trees shipped to the farmers had been actually planted. It should be stated in this

connection that good cultivation does not mean deep cultivation. Experience with orchards has shown that shallow cultivation does less damage to the roots and is more beneficial to the trees. There is no reason to believe that this will not hold true with windbreak trees. Therefore shallow cultivation is recommended.

However, the frequency of the breaks in the rows is fairly good evidence that large numbers have died from neglect. As might be expected, the conifers were much more seriously affected than the hardwoods. In several cases the comparative thriftiness of the trees in one part of a plantation, where they had been cared for, and the poor condition of a neglected part of the same windbreak showed pretty clearly that cultivation had been the determining factor.

Table 26 shows the comparative height growth of all the species in the demonstration windbreaks for the first five years after planting.

**Table 26**

**Average Height Growth in All Demonstration Windbreaks by Species for 4-, 5-, and 6-Year-Old Plantations***

| Species | Well cultivated | | Poorly cultivated | | Increased growth due to cultivation |
|---|---|---|---|---|---|
| | Av. height growth | No. of trees | Av. height growth | No. of trees | |
| | ft. | | ft. | | per cent |
| American elm | 1.76 | 1,884 | 1.26 | 452 | 40 |
| Eastern white cedar | 1.39 | 732 | .... | .... | ... |
| Boxelder | 1.65 | 1,032 | 1.18 | 349 | 40 |
| Silver maple | 2.14 | 1,265 | 0.98 | 61 | 118 |
| Caragana | 0.75 | 1,067 | 0.64 | 359 | 17 |
| Eastern cottonwood | 1.80 | 396 | 1.65 | 375 | 9 |
| Northwest poplar | 1.20 | 208 | .... | .... | ... |
| Russian poplar | 1.70 | 509 | 0.94 | 340 | 81 |
| Green ash | 1.55 | 2,200 | 1.10 | 1,292 | 41 |
| Jack pine | 1.01 | 1,440 | 0.77 | 161 | 31 |
| Norway pine | 0.52 | 1,307 | 0.40 | 259 | 30 |
| Scotch pine | 0.68 | 1,245 | 0.72 | 280 | —5.6† |
| Eastern white pine | 0.74 | 109 | 0.72 | 41 | 2.8 |
| Blue spruce | 0.30 | 511 | 0.40 | 202 | —25† |
| Norway spruce | 0.35 | 159 | 0.30 | 128 | 17 |
| White spruce | 0.35 | 1,225 | 0.35 | 73 | 00 |
| Laurel-leaf willow | 1.66 | 341 | 1.04 | 140 | 60 |
| White willow | 2.19 | 164 | 1.05 | 138 | 109 |
| Russian olive | 1.47 | 237 | 1.55 | 166 | —5† |
| Total | .... | 16,031 | .... | 4,816 | ... |

* Average = mean annual.
† Decrease.

It is evident from Table 26 that the greatest mean annual height growth under good cultivation for the first five years after planting may be expected from white willow and silver maple. They respond by far the best to cultivation.

Eastern cottonwood, American elm, boxelder, and laurel-leaf willow all make about the same rate of growth, with eastern cottonwood slightly

in the lead. In view of the facts in regard to the older plantations, the cottonwood apparently makes a much faster relative growth a little later in life. Russian poplar also belongs in this group, on the basis of rate of growth, but drawbacks make it unworthy of much consideration.

Green ash is only a little slower than boxelder. If its long life, the high quality of the wood produced, its great hardiness, and its freedom from insects and diseases are considered, it is probably the most satisfactory hardwood tree for the prairie plantation.

The jack pine is by far the fastest grower among the conifers. Its mean annual height growth for the first five years is slightly over a foot, northern white pine is next with 0.74 foot, Scotch pine next with 0.68 foot, and Norway pine last among the pines with 0.52 foot.

There is a very little difference in the rate of growth of the three spruces. In general, they grow only about half as fast the pines.

## MULCHING AS A SUBSTITUTE FOR CULTIVATION

Experience in Europe has proved that ground on which no trees have grown for many years is a poor site for tree growth. The indications are that the adverse conditions are due to the compactness of the soil and the lack of old tree roots down the course of which, or even through which, the young roots most easily penetrate the soil. If this is true of areas which have been cleared of forests in comparatively recent times, how much more would it be true on prairie lands, which have never grown trees, or at least not for thousands of years.

The writer, therefore, was prepared to see the failure of the mulching practice in the prairie plantations. Where the mulch was applied soon after the trees were planted and was maintained later the failure is absolute; growth is badly stunted and many of the trees are dead. The trees are apparently no better off than where weeds have been allowed to grow.

But where thoro cultivation was practised for three or four years after the establishment of the plantation and then a heavy mulch was applied, there is a different story. This was also noted by Longyear. Some of the best plantations examined had been treated in that way, and showed every sign of thrift, probably because the years of cultivation make possible the better aeration of the soil.

This suggests, as the best possible practice, cultivation as long as it can be conveniently carried on without injuring the trees, then the application of a heavy mulch to serve the same purpose as the leaf litter which will eventually form.

## COMPARATIVE VALUE OF SPECIES

**American elm** (*Ulmus americana*)

This species is inferior to green ash, but grows faster. It ranks a close second to green ash as a long-lived windbreak tree, and probably should be placed ahead of it where protection from wind is the only object. It appears to be altogether hardy everywhere in the state, and is affected much less by neglect than is the ash or many other of the hardwoods. It is less affected by drouth than cottonwood, willow, or soft maple.

**Blue spruce** (*Picea pungens*)

Blue spruce has been very little used for windbreak planting, probably because the blue specimens are so expensive. The blue ones, however, are only freaks, and the common green ones, which are not so much in demand or so costly, are quite as good for windbreak planting. It grows slightly slower than the other spruces, but is better adapted to growth in heavy gumbo soils. It produces very dense foliage and will grow in very dense stands. Its susceptibility to attacks of plant lice makes its planting in large numbers, in any other than gumbo soils (which are unsuited to other species), a matter of doubtful judgment.

**Boxelder** (*Acer negundo*)

The boxelder is one of the hardiest pioneer trees and can get along under almost any conditions. Its early growth is almost as fast as that of cottonwood. It forms a dense shade and is capable of producing forest conditions more quickly than most other species. Its poor form and the comparatively poor quality of its products, even for cordwood, are its chief drawbacks. It breaks easily in the wind and has suckers. It harbors many undesirable insects.

**Caragana** (*Caragana arborescens*)

This species is a shrub which attains a height of only six to ten feet, but its extreme hardiness, its ability to grow in very dry situations, and its dense, bushy form make it very desirable for prairie windbreaks and snow fences. It is especially suitable for planting along the outer edge of an old, hardwood windbreak to prevent the snow from blowing through.

**Cottonwood** (*Populus deltoides*)

This is one of the species most commonly planted on the prairies. It is found in practically every prairie county. Its growth for the first few years is slightly less than that of soft maple, but it later outgrows all other species. It has a straighter, clearer form than most other species and produces a more usable product than any other hardwood except green ash. It is not sensitive to neglect, is hardy everywhere,

and has a very thrifty appearance. Its coarse, sparse branching and thin foliage are its greatest drawbacks as a windbreak tree.

**Green ash** (*Fraxinus pennsylvanica var. lanceolata*)

The growth of green ash is 75 per cent as fast as that of the cottonwood and its coarse branches and light foliage detract from its value for windbreaks. On the other hand, its long life and good form, the value of its products, and its ability to seed in naturally under the cottonwoods, make it one of the most valuable of the hardwoods. It is safe to say that any prairie plantation will be more valuable for a mixture of green ash.

**Jack pine** (*Pinus banksiana*)

Jack pine makes the most rapid growth of any of the conifers except the European larch, which is not an evergreen. It can not grow under the shade of any other trees, not even under the very light shade of the cottonwood, but it is capable of forming very dense stands by itself or with other trees no taller than itself. These traits, together with its ability to grow on very sandy soil and its resistance to very severe drouth, make it a close competitor of the white spruce for the leading place as a windbreak tree. It should be planted much more than it is.

**Laurel-leaf willow** (*Salix pentandra* or, as the horticulturists call it, *Salix laurifolia*)

This species has a very dense form, well adapted to windbreaks, but grows slightly slower than white willow. Its glossy leaves give the tree a striking appearance and it looks well in a plantation, but its showing in these demonstration windbreaks does not prove its superiority over the white willow, which seemed to be equally hardy. It does not show the thrifty condition which was expected.

**Northern white cedar** (*Thuja occidentalis*)

This species seems not to be very successful under prairie conditions. There were many blank places in the plantations, the growth was erratic, and the form none too good.

**Northern white pine** (*Pinus strobus*)

This species is doing well wherever it is found. In a few cases it is making a sensational growth. In one grove at St. James, trees twenty-six years old average from 6 to 10 inches in diameter, and are 50 feet tall. In another plantation near Freeport, white pines seven years old were 13 feet tall. The foliage is dense enough to form an excellent windbreak even tho the tree will not stand as close crowding as the spruce.

White pine blister rust may seriously damage white pine. It comes from infections on gooseberry and currant bushes. Therefore, if there

are no cultivated black currants within a mile, and no other currants or gooseberries within 1,500 feet, the pine should be comparatively safe. The chance of infection in these isolated plantations should be slight if thesce simple preventive measures are taken.

**Norway pine** (*Pinus resinosa*)

The red, or Norway, pine seems to make the slowest growth of any of the pines used in prairie plantings in this state. Moreover, its tendency to lose its lower branches early and to form a comparatively open stand detract from its value as a windbreak tree. Its ability to make a straight, sturdy growth and to produce valuable lumber, make it a worth-while tree in any plantation, but it is not highly recommended for windbreaks.

**Norway spruce** (*Pices excelsa*)

This species makes the most rapid growth of any of the spruces. The figures given in the tables are a little misleading because they represent only the first eight or nine years of growth, and the spruces do not begin the more rapid growth of later life until they are at least six years old. Norway spruce will later approach, if, indeed, it does not exceed, the rate of growth of the jack pine.

Like blue spruce, the Norway spruce forms a dense stand. In the southern third of the state it is one of the best evergreen trees. No plantations are found in the northern part of the state, but its success in the arboretum at the Cloquet Forest Experiment Station, where it is far exceeding in growth all the other species on a rather light soil, seems to indicate that it should be as successful there as farther south.

**Northwest poplar** (*Populus sp.*)

This tree is a fairly rapid grower and quite hardy, but poplar canker on many trees throws some doubt upon its value for windbreak planting.

**Russian olive** (*Eleagnus angustifolia*)

Unfortunately, this species is found in very few of the demonstration windbreaks, and not at all in the well cultivated ones. Under poor cultivation it is second only to cottonwood in its rate of height growth. It has, moreover, the ability to grow in alkaline soils better than any of the other species. It is a small tree, seldom exceeding 25 to 30 feet in height.

**Russian poplar** (*Populus petrowskiana*)

This tree is a close competitor of the white willow in height, but is so susceptible to attacks of poplar canker that it seems to be wholly unreliable. Many of the six- and seven-year-old trees have been killed by this disease.

**Scotch pine** (*Pinus sylvestris*)

Scotch pine is a close rival of jack pine in height growth, but is inferior to it as a windbreak tree in many other respects. It has a much more open form, a less dense foliage, and is unable to stand close crowding. Scotch pine does not grow as straight as jack pine and its timber is, therefore, of less value. It has some value as an ornamental tree and as a stop-gap when planted in the inside of a hardwood windbreak, otherwise it ranks low in such a plantation.

**Silver maple** (*Acer saccharinum*)

Silver maple is the fastest grower of the windbreak trees during the first few years. This feature, together with its many branches and rather dense foliage, makes it desirable as a windbreak tree. Contrary to general opinion, this species breaks very little in the wind. It is, however, very susceptible to rot when it does break, and wounds should be taken care of promptly. It also shows severe frost injury in several plantations on heavy soil in the northern prairies.

**White spruce** (*Picea glauca*)

White spruce is one of the most, if not the most, satisfactory windbreak tree available in this state. The United States Great Plains Experiment Station, at Mandan, North Dakota, considers it, especially the Black Hills variety, as an almost ideal windbreak tree.

It maintains a dense foliage, will grow in a dense formation, is perfectly hardy, resistant to disease, long-lived, has a good form, and produces a readily saleable product. Its growth is much slower than that of the jack pine, but later on will be much faster than the figures shown in the tables. More of it should be planted.

White willow (*Salix alba*)

This species ranks fourth in height growth. Like the silver maple, it seems very sensitive to neglect and the growth falls off over 50 per cent under poor cultivation. In many cases it produces two or more stems. This may be a drawback in the production of saw logs, but is probably an advantage in the production of fence posts and cordwood. It also helps to make denser growth for wind protection. It seems perfectly hardy everywhere and is a good tree for windbreak planting where long life is not a necessity. It has, moreover, the ability to sprout prolifically from the stump, and thus renews itself quickly.

## SUMMARY

1. There is practically no place on the Minnesota prairies, with the possible exception of small patches of alkaline soil, where trees of some species can not be grown.

2. There is so little difference in the soil and climate of the prairie region of this state that all the trees planted in the southern half of the state, with the possible exception of black walnut and, in a few places, soft maple, may be safely planted in the north, and vice versa.

3. A well cultivated windbreak of the better species described and located on prairie soil attains an average height of 13 feet in seven years.

4. Good cultivation increases the growth of most species by 10 to 50 per cent.

5. Mulching is of no value during the first three years after planting, but can be done to advantage after three years of good cultivation.

6. Soil moisture within two feet of the surface within the grove is only about 1.5 per cent lower than that outside the grove.

7. The life of such river-bottom trees as willow, cottonwood, box-elder, and silver maple is apparently shortened by the unaccustomed drouth of the prairies.

8. Green ash and American elm are the most satisfactory hardwoods, and jack pine and white spruce the most satisfactory conifers for prairie planting where large and long-lived trees are desired; but cottonwood, willow, silver maple, and Russian olive deserve serious consideration where quick growth is wanted and a short life is no drawback.

9. Rabbits greatly injure small trees. The American elm seems to be the favoriate food, but no species is exempt. According to general report, the cottontail is more destructive than the jack rabbit.

10. The humidity of the air within the grove is from 2 to 3 per cent higher than that in the open.

11. The few readings taken indicate that the effect of the windbreak upon wind velocity is quite considerable even at the distance of twenty tree heights to leeward.

12. A snow trap in a windbreak stops the drifting of the snow on the lee of the trees by the formation of a back eddy in the opening.

13. There is a distinct draft between the trunks of a single row of trees that carries through the snow and piles it to leeward of the trees.

14. The willow, cottonwood, and silver maple trees in the old plantations are mostly dying in the tops at an age of 30 to 40 years. The situation demands immediate action, and the conditions within the plantations are, in most cases, ideal for underplanting.

15. Trees planted 4 feet apart in rows 8 feet apart require thinning when they are fifteen years old, if the thrift and rate of growth of the plantation is to be maintained.

16. A good windbreak, even when young, adds materially to the sale value of a farm.

## RECOMMENDATIONS

1. The benefits derived from shelter belts around farm buildings are sufficient to warrant their planting on every prairie farm that does not already have one.

2. Windbreaks on the south side of fields will probably more than pay for the ground they occupy. Moreover, the planting of large numbers of such windbreaks might do much to prevent the formation and occurrence of the destructive, dry, southwest winds.

3. Alfalfa, timothy, clover, or other permanent hay crops should be planted in a four-rod strip on either side of the windbreaks. Such crops are injured little by the neighboring trees. The grain crops would then receive all the advantages of this windbreak and suffer none of the disadvantages.

4. The older windbreaks of eastern cottonwood, willow, and silver maple, that are now dying in the tops, should be underplanted to ash or evergreen trees. The dying trees should be gradually cut out as the underplanted trees grow up to take their places.

5. Where the old shelter belt has been planted too close to the buildings, a new planting should be made outside of it. This will stop the drifting of snow. When the new shelter belt has become tall enough, the old one may be cut away completely or kept as a wood lot.

6. One or more rows of evergreens, such as jack pine or spruce, should be included in every new shelter belt and added to every old one. The same is true of the better, longer-lived hardwoods such as green ash and white elm. These not only make the shelter belt tighter and more permanent, but they also add greatly to the winter appearance of the farm.

7. For best results the plantation should be cultivated well for at least three years after planting and then treated with a heavy mulch. Earlier mulching is harmful rather than beneficial.

8. Do not plant a shelter belt closer than 100 feet to the farm buildings.

9. A combined woodlot and shelter belt is economical and makes a satisfactory protection.

10. Do not allow stock to graze in a plantation or use it as a place for machinery.

11. After a plantation spaced 4 or 8 feet is fifteen years old it will need thinning. Do not hesitate to cut out some of the trees where they appear to be too thick. It will improve the growth of the remaining trees and increase the later value of the windbreak.

12. Do not begrudge the land occupied by a good windbreak or shelter belt; it is producing as much as any other land on the farm.

## REFERENCES

1. Trenk, F. B.
1927 Windbreaks and shelter belts in Maryland. University of Maryland, State Dept. of Forestry.
2. Bates, Carlos G.
1924 The windbreak as a farm asset. In U.S. Dept. of Agr. Farmers Bull. 1405.
3. ———.
1911 Windbreaks. Their influence and value. U. S. Dept. of Agr. Forest Service Bull. 86.
4. Bode, I. T.
1922 The shelterbelt as an asset on the Iowa farm. In Iowa Extension Service Bull. 108.
5. Records, P. C.
1911 Tree planting for shelter in Minnesota. Minnesota Forest Service Bull. 1.
6. Anonymous
Renewing the shelterbelt. Iowa Agr. Expt. Sta. Circ. 27.
7. Macdonald, G. B.
1917 Evergreen trees for Iowa. Iowa Agr. Expt. Sta. Bull. 170.